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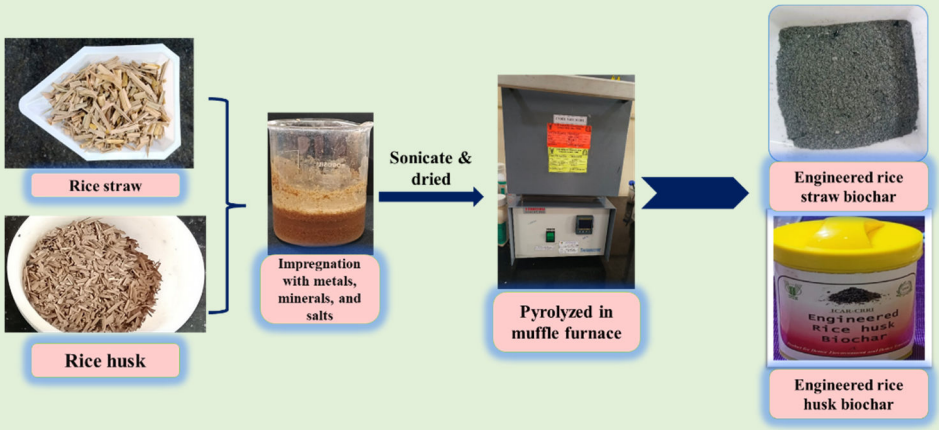
TARGETED ADSORPTIVE REMEDIATION OF PESTICIDE-CONTAMINATED WATER USING ENGINEERED RICE HUSK



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Prologue

Point source contamination of xenobiotics including pesticides, antibiotics and phosphates are a ubiquitous problem worldwide. The pollution is mostly occurrs due to excessive and often unregulated application of agrochemicals, including pesticides, as well as the indiscriminate use and improper disposal of antibiotics in agricultural and pharmaceutical sectors. The point source contamination of above-mentioned pollutants directly and indirectly affects our environment; mostly the water bodies including groundwater, thereby posing serious ecological and public health risk while also accelerating the emergence of antimicrobial resistance. There are two ways to make the contaminated water free from the pollutants: either by decontaminating already polluted water or by preventing contamination in the first place. Of these, prevention is widely regarded as more sustainable, simpler and safer option. Among the different methods for controlling point source pollution, adsorption-based technologies are particularly appealing because they are

simple, effective, and have the potential for environment friendly use. Among the various adsorbents used as decontaminating agents, biochar emerges as a highly promising option, especially when derived from agricultural wastes like rice straw and husk, as it offers a cost-effective and sustainable solution by simultaneously addressing biomass waste and reducing methane emissions. The use of conventional biochar derived from agricultural residues is a widely adopted practice for pollutant removal. However, pristine biochar has certain limitations, such as a negatively charged surface, low surface area, hydrophobicity, and longer sedimentation time. To overcome these drawbacks, functionalizing biochar with various metals, minerals, and salts has proven effective in enhancing its sorption capacity. This bulletin highlights the development and use of novel, low-cost, and environmentally safe engineered adsorbents to minimize or prevent point source contamination from pesticides. It presents the synthesis methods, functional enhancements, and real-world applications of these engineered materials, offering a pathway to cleaner water systems and stronger environmental management practices.

Preparation

a. Zinc and bentonite clay modified engineered rice husk biochar composite (ERHB)

Rice husk powder and bentonite clay (2:1) were treated with 5 g $ZnCl_2$, sonicated for 30 mins, incubated overnight, and dried at 80 ºC for 6-8 h. After nitrogen purging, the mix was sealed and pyrolyzed at 500°C for 2 hours. The resulting Zn- and clay-modified biochar removed 76.24% of imidacloprid, 97.08% of bispyribac sodium, and 83.79% of carbendazim from contaminated water.

b. Biogenic magnesium oxide-rice husk biochar composite (MgO RHBC)

A mixture of 5% purple rice plant extract, magnesium nitrate hexahydrate (5 g), and 10 g rice husk powder was heated at 80 °C with continuous stirring. NaOH (1M) was added dropwise until the color changed from purple to yellowish-brown. After 2 hours of reaction, the residue was dried at 60°C for 4 h and calcined at 500°C for 2 hours under anaerobic conditions to form MgO rice husk biochar composites. The biochar composite was successfully utilised as an adsorbent for the removal of 75.75% of thiamethoxam, 79.65% of chlorpyriphos and 77.66% of fenpropathrin from contaminated water.

c. Manganese modified paddy husk biochar (Mn-PHB)

Rice husk powder (10 g), $MnCl_2$ (5 g) and bentonite (5 g) were blended in 50 mL of distilled water, sonicated for 15 minutes, soaked overnight, and dried

at 80°C for 4 h. After nitrogen purging and sealing, it was pyrolyzed at 500°C for 2 hours. The resulting Mn-PHB removed 78.34% of tetracycline from contaminated water.

d. Calcium carbonate-enriched rice straw biochar (CRSB-3)

Rice straw biomass (15 g) was immersed in a slurry of 150 mL calcium carbonate (3 g) solution for 24 h, after which the mixture underwent 1 h of sonication. The resulting biomass was then oven-dried at 85 °C for 12 h. Subsequently, the dried biomass was pyrolyzed at 700 °C for 2 h in a muffle furnace. This calcium carbonate-enriched rice straw biochar could remove 73.71% of phosphate, 47.19% of lead, 63.51% of arsenic, 100% of cadmium and 84% of glyphosate from wastewater.

Efficiency

Adsorbent	Target pollutants	Maximum adsorption capacity (µg mg^{-1})	Reusability
ERHB	Pesticides	57.69	Minimum 5 times
MgO RHBC	Pesticides	283.84	Minimum 3 times
CRSB-3	Phosphate, glyphosate and heavy metals	70.79	Minimum 3 times
Mn-PHB	Tetracycline	27.28	Minimum 3 times

Salient features

1. The composites are prepared from agro-wastes namely rice husk or straw.
2. The composites are having high sorption potentials ranged from 27.28 to 283.84 µg mg^{-1}.
3. The composites could be reused for minimum 3 times.
4. After utilisation, the products can easily be incinerated to rid-off sorbed xenobiotics.

Market potential

This technology can be adopted by central and state governments, farmers, pesticide retailers, and pesticide manufacturers. To encourage its widespread use, it should be promoted through on-farm demonstration, farmer training, awareness programme etc. Additionally, government bodies should provide incentives to farmers to implement this adsorbent in their agricultural practices.

Operational procedure

To decontaminate the water samples containing pesticides (below 100 ppm), 100 g of biochar can be added to 750 mL of water, shaken for 10 minutes, and then left undisturbed for 30 minutes to remove pesticides more than 65% of applied quantity. The same setup can be left undisturbed for 12 hours, which will result in removal of more than 95% of the pesticides. The same adsorbent can be reused 2 to 5 times, depending on the type and concentration of the pollutants.

Targeted adsorptive remediation of pesticide-contaminated water using engineered rice husk

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